CHAPTER 6

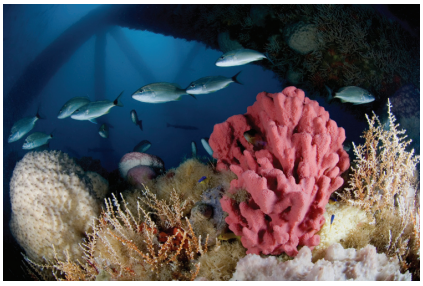
NOAA Research & Development

NOAA research scientist Randy Johnson inpsecting an autonomous weather balloon

NOAA RESEARCH & DEVELOPMENT

NOAA is the single federal agency with operational responsibility to protect and preserve ocean, coastal, and Great Lakes resources and to provide critical and accurate weather, climate, and ecosystem forecasts that support national safety and commerce. NOAA seeks to accomplish this mission by addressing the grand environmental challenges facing our nation today and in the decades to come. We have captured the most pressing of these challenges in our most recent *5-Year Research Plan* as a set of six overarching questions. Answers to these questions will provide the public and policy makers with the understanding needed to make well-informed decisions now and in the future.

Following are a small selection of the research and development accomplishments from the past fiscal year for each of these grand research challenges.



Sponge and fish under Navy Tower, Offshore Georgia

What factors, human and otherwise, influence ecosystem processes and impact our ability to manage marine ecosystems and forecast their future state?

NOAA SCIENTISTS DEVELOP SIMPLE MODEL TO PREDICT GLOBAL PATTERNS IN MARINE ENERGY TRANSFERS

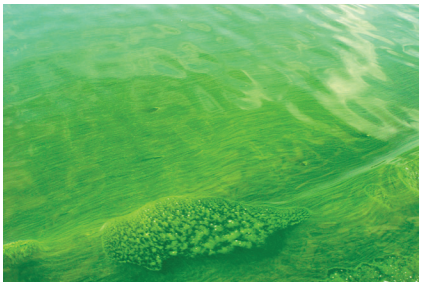
In 2009, NOAA federal scientists published a key study - *Controls on the Ratio of Mesozooplankton Production to Primary Production in Marine Ecosystems* - on global patterns in the transfer of energy from phytoplankton to mesozooplankton, which supports nearly all ocean life. Understanding and modeling global energy transfers in the marine ecosystem is critical for informed management of fisheries and coastal resources. In this case, mesozooplankton are an important food source for larger fish and form the base of the marine food web. The model developed in this study is presently being integrated into NOAA's Earth System Model. The Earth System Model is an example of the world-class science at NOAA's Federal research facilities.

POLYBROMINATED DIPHENYL ETHERS (PBDE) - AN EMERGING CONTAMINANT OF CONCERN IN U.S. COASTAL ZONES

NOAA's National Status and Trends program released results from the first national assessment of polybrominated diphenyl ethers (PBDE). PBDEs are a fire retardant and are used in multiple industries. The NOAA assessment showed PBDEs are widely distributed throughout the U.S. coastal zone and concentrations were correlated with human population density, with the highest concentrations found in urban areas. This is significant, because, con-

centrations of PBDEs in breast milk are ten times higher in the United States when compared to Europe. The proliferation of PBDEs has greatly increased the need for an early warning network that will provide relevant information to resource managers, legislators and regulators who are charged with protecting human health and our resources. To address this threat, NOAA has refocused its resources to monitor for contaminants of emerging concern and to develop an early warning network that would trigger responses from other agencies and forecast chemical threats into the future. Partners in this endeavor include the US EPA, USGS, various state organizations such as the Southern California Coastal Water Resources Project and other elements of the Department of Commerce.

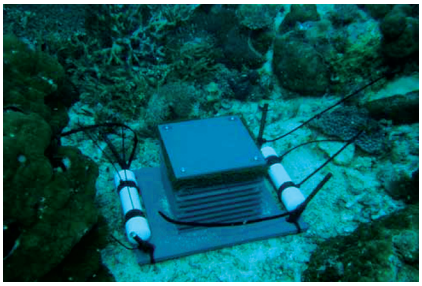
BREAKTHROUGH DISCOVERY DEEPENS UNDERSTANDING OF WHY ALGAE FORM BLOOMS



Microcystis bloom in Hamilton Harbor, Lake Ontario

A new discovery provides new insight into why marine algae form blooms. NOAA researchers from the National Centers for Coastal Ocean Science, working alongside funded counterparts in California and Scotland, found that certain bacteria occurring in red tide blooms convert iron, a critical nutrient, into a form particular algae can absorb. Scientists have long understood that certain species of bacteria are closely associated with the microalgae that form these blooms, but did not understand why they formed or what role the bacteria play. The researchers noticed that these bacteria release a chemical which helps the bloom-forming algae absorb iron, a nutrient essential for photosynthesis. The algae, in turn, release organic compounds to support the growth of the bacteria. This relationship between the bacteria and the algae is known as symbiosis. The new insight will help scientists and environmental managers develop more realistic bloom formation models, which will improve prediction and mitigation strategies. These microscopic plants support world fisheries and help regulate climate, but toxic species can cause harm. Robust models that predict the formation of both types of blooms require a fundamental knowledge how these complex interactions work.

What is the current state of biodiversity in the oceans, and what impacts will external forces have on this diversity and how we use our oceans and coasts?



An Autonomous Reef Monitoring Structure (ARMS), like the one shown, is designed to mimic the reef environment and attract colonizing coral reef organisms.

AUTONOMOUS REEF MONITORING STRUCTURES (ARMS): A NEW TOOL TO SYSTEMATICALLY MONITOR OCEAN FLOOR BIODIVERSITY

Marine biodiversity is seriously threatened by climate change and ocean acidification resulting from the absorption of increasing amounts of CO2 from the atmosphere. As part of the Census of Marine Life's Census of Coral Reef Ecosystems (CReefs) project, the NOAA Pacific Islands Fisheries Science Center's Coral Reef Ecosystem Division (CRED) has led a successful inter-

national effort to develop Autonomous Reef Monitoring Structures (ARMS) as a standardized tool to obtain indices of the biodiversity of poorly-known bottom dwelling, or benthic, organisms, that comprise the vast majority of the diversity of coral reefs.

ARMS are small, simple structures which mimic the complexity of reef habitats and allow a multitude of organisms to settle on their various surfaces. Upon collection, organisms are removed, identified, preserved, and then subjected to molecular analyses. Advanced molecular techniques such as DNA barcode analysis and mass-parallel community genomics enable rapid development of indices organism biodiversity in the reef scientists an unprecedented ability to establish a global baseline of the spatial patterns and temporal changes of biodiversity. The biodiversity and other metrics provided by ARMS will both improve marine spatial planning needed to effectively implement ecosystem-based management and enhance our ability to predict the ecological impacts of climate change and ocean acidification.

INVESTIGATING MARINE ORGANISM DISTRIBUTION AS WATER TEMPERATURES VARY

Changes in the distribution of marine organisms have been observed in many regions, including the Bering Sea and the Northeast U.S. continental shelf. NOAA scientists made important advances in understanding these observed distribution shifts in 2009. A significant finding for the Bering Sea was that during periods of warmer, increased water temperatures, production of large prey items for larval and juvenile walleye pollock decreased, but when colder conditions return, large prey populations rebound. This understanding is critical to explain how climate change may impact Alaska's walleye pollock fishery, the largest fishery in the U.S.

Similarly, a study published in 2009 by NOAA scientists examined causes for changes in the spatial distribution of marine fish in the Northeast U.S. continental shelf ecosystem. Many stocks exhibited a poleward shift in their center of biomass, most with a concurrent increase in depth. Stocks from the southern extent of the survey region exhibited greater poleward shifts. Large-scale temperature increases and changes in ocean circulation were found to be the most important factors associated with the shifts in mean distributions.

A Polar Bear roaming the icy waters of Svalbard

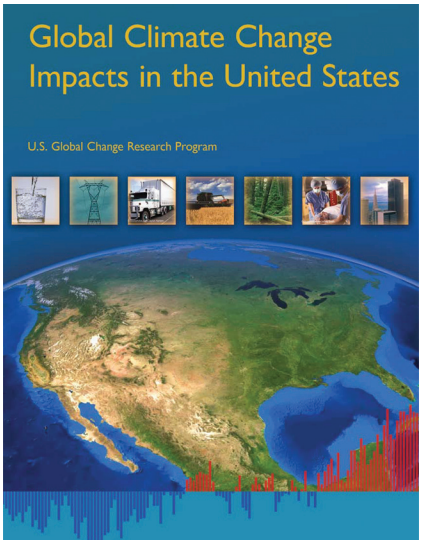
What are the causes and consequences of climate variability and change?

NEW STUDY SHOWS CLIMATE CHANGE LARGELY IRREVERSIBLE

A new scientific study led by the National Oceanic and Atmospheric Administration reaches a powerful conclusion about the climate change caused by future increases of carbon dioxide: to a large extent, there's no going back.

The pioneering study, led by NOAA senior scientist Susan Solomon, shows how changes in surface temperature, rainfall, and sea level are largely irreversible for more than 1,000 years after carbon dioxide (CO_2) emissions are completely stopped. The study examines the consequences of allowing CO_2 to build up to several different peak levels beyond present-day concentrations of 385 parts per million and then completely halting the emissions after the peak. The authors found that the scientific evidence is strong enough to quantify some irreversible climate impacts, including rainfall changes in certain key regions, and global sea level rise.

WHITE HOUSE RELEASES LANDMARK CLIMATE CHANGE REPORT



Global Climate Change Impacts in the United States

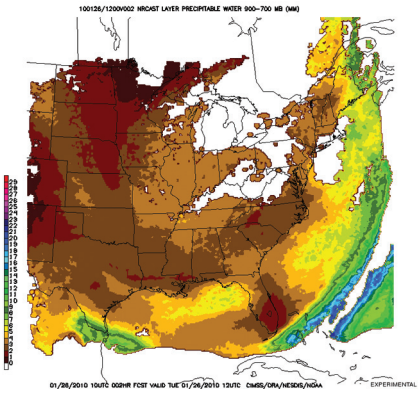
Climate change is already having visible impacts in the United States, and the choices we make now will determine the severity of its impacts in the future, according to a new and authoritative federal study assessing the current and anticipated domestic impacts of climate change.

The report, "Global Climate Change Impacts in the United States," compiles years of scientific research and takes into account new data not available during the preparation of previous large national and global assessments. It was produced by a consortium of experts from 13 U.S. government science agencies, including NOAA, and from several major universities and research institutes.

Among the main findings are:

- Heat waves will become more frequent and intense, increasing threats to human health and quality of life. Extreme heat will also affect transportation and energy systems, and crop and livestock production.
- Increased heavy downpours will lead to more flooding, waterborne diseases, negative effects on agriculture, and disruptions to energy, water, and transportation systems.
- Reduced summer runoff and increasing water demands will create greater competition for water supplies in some regions, especially in the West.
- Rising water temperatures and ocean acidification threaten coral reefs and the rich ecosystems they support. These and other climate-related impacts on coastal and marine ecosystems will have major implications for tourism and fisheries.
- Insect infestations and wildfires are already increasing and are projected to increase further in a warming climate.
- Local sea-level rise of over three feet on top of storm surges will increasingly threaten homes and other coastal infrastructure. Coastal flooding will become more frequent and

severe, and coastal land will increasingly be lost to the rising seas.



Experimental Eastern United States Near-Cast Model of Precipitable Water (Two-Layer Difference)

What improvements to observing systems, analysis approaches, and models will allow us to better analyze and predict the atmosphere, ocean, and hydrological land processes?

"NEARCASTING" EARLY WARNINGS FOR SEVERE WEATHER

Forecasters have had very few tools available to provide early warnings of severe weather. A new model developed by scientists from NOAA's Center for Satellite Applications and Research could bridge that gap in knowledge. The new model could predict the likelihood of severe weather formation up to six hours in advance by using multi-layer water vapor information from the NOAA Geostationary Satellite (GOES-12 sounder) to track regions where upper level drying is occurring over low-level moistening. Rapid change in the vertical lapse rate of moisture is often a precursor to severe weather development. NOAA scientists worked with scientists at the University of Wisconsin / Cooperative Institute for Meteorological Satellite Studies to develop and test the near-cast model, and the National Weather Service Forecast Office in Milwaukee, Wisconsin coordinated evaluation of the severe weather "nearcasting" product.

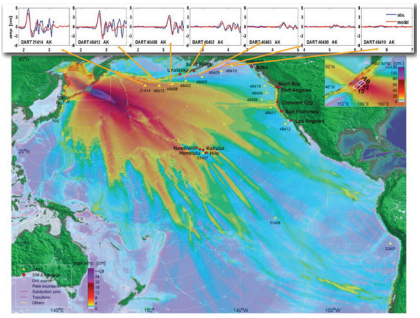
How can the accuracy and warning times for severe weather and other high-impact environmental events be increased significantly?

EXTENDING WARNING LEAD TIMES FOR SEVERE WEATHER EVENTS

A move from "warn on detection" to "warn on forecast" paradigm will extend warning lead times. NOAA's National Severe Storms Laboratory is conducting study ensembles for very short-range (0 to 1 h) forecasts of severe weather events. These ensembles assimilate Doppler radar data into cloud-scale numerical models to provide improved predictions of thunderstorms and their associated severe weather. While still in a research mode, initial results suggest that it may be possible to use these forecasts in warning operations, leading to a shift from the present "warn on detection" strategy to a "warn on forecast" strategy that would provide longer lead times for severe weather events. NOAA's National Weather Service warnings today are largely based upon detection of severe weather phenomena or precursors that imply imminent occurrence of the phenomena. The National Severe Storms Laboratory

is leading a multi-organizational effort to use high resolution models to help predict such phenomena with much greater warning lead times. A warn-on-forecast system is envisioned as a probabilistic convective-scale ensemble analysis and forecast system that assimilates in-storm observations into a high resolution convection-resolving model ensemble. While a number of scientific and cultural challenges still need to be overcome, the potential benefits are significant.

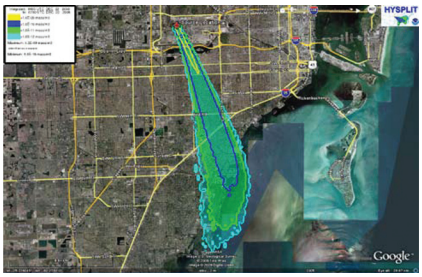
TSUNAMI DATA FOR COASTLINE COMMUNITIES



Propagation database forecast comparison with data from DART® tsunami buoys for the 15 November 2006 Kuril tsunami (red line = model, blue line = buoy data)

NOAA's Pacific Marine Environmental Laboratory installed the latest version of the Short-term Inundation Forecasting for Tsunamis (SIFT) system at NOAA's two U.S. Tsunami Warning centers operated by the National Weather Service. Installation of SIFT V3.0 was completed at both the West Coast and Alaska Tsunami Warning Center in Palmer, Alaska and the Pacific Tsunami Warning Center in Ewa Beach, Hawaii during the week of June 15, 2009. For the first time, SIFT V3.0 incorporates deep ocean real-time tsunami data into real-time inundation models for 32 at-risk coastal communities. The first test of the system was the September 30, 2009, Samoan tsunami which killed over 100 people. During this tsunami warning, the SIFT system corrected assimilated deep ocean tsunami data into models that forecast Hawaii and the U.S. west coast would not be flooded. This accurate forecast meant Hawaii could avoid about $70M in unnecessary evacuation costs. These community models will eventually be used to provide real-time wave height and current forecasts for a particular community during a tsunami event. Once operationally accepted, SIFT V3.0 will add a critical component to each tsunami warning center's capability to accurately predict how a tsunami wave will impact a particular coastline community.

DISPERSION OF TOXIC RELEASES



HySPLIT model example displayed with Google Earth

NOAA's Air Resources Laboratory is enhancing their Hybrid Single Particle Lagrangian Integrated Trajectory (HySPLIT) dispersion model to enable it to accurately model over 500 different types of hazardous substances. HySPLIT also uses very high-resolution Weather Research and Forecast (WRF) model data from NOAA's Earth System Research Laboratory to more accurately model the trajectory and dispersion of the toxic release. The WRF model, HySPLIT dispersion forecasts, and detailed weather data are provided to emergency managers and local forecasters using a net-enabled collaborative workstation that provides tools enabling emergency managers and forecasters to quickly assess and provide more accurate response and mitigation plans to the public.

HYSPLIT is designed to support a wide range of simulations related to the atmospheric transport and dispersion of pollutants and hazardous materials, as well as the deposition of these materials (such as mercury) to the Earth's surface. Some of the applications include tracking and forecasting the release of radioactive material, volcanic ash, wildfire smoke, and pollutants from

various stationary and mobile emission sources. Operationally, the model is used by NOAA's National Weather Service through the National Centers for Environmental Prediction and at local Weather Forecast Offices.

How are uncertainties in our analyses and predictions best estimated and communicated?

NOAA'S NATIONAL WEATHER SERVICE DELIVERS IMPROVEMENTS IN PROBABILISTIC HYDROLOGIC FORECASTING

The Office of Hydrologic Development, in NOAA's National Weather Service, completed the initial version of its new Hydrologic Ensemble Forecast System (HEFS). After several years of research, and prototyping at River Forecast Centers across the country, HEFS is now being delivered for use in operations. HEFS will improve NOAA's probabilistic hydrologic forecasts by:

(1) incorporating temperature and precipitation forecasts from numerical weather prediction models;

(2) allowing hydrologic forecasts with lead times from hours to seasons to be created without discontinuities between forecasts of different lead times; and,

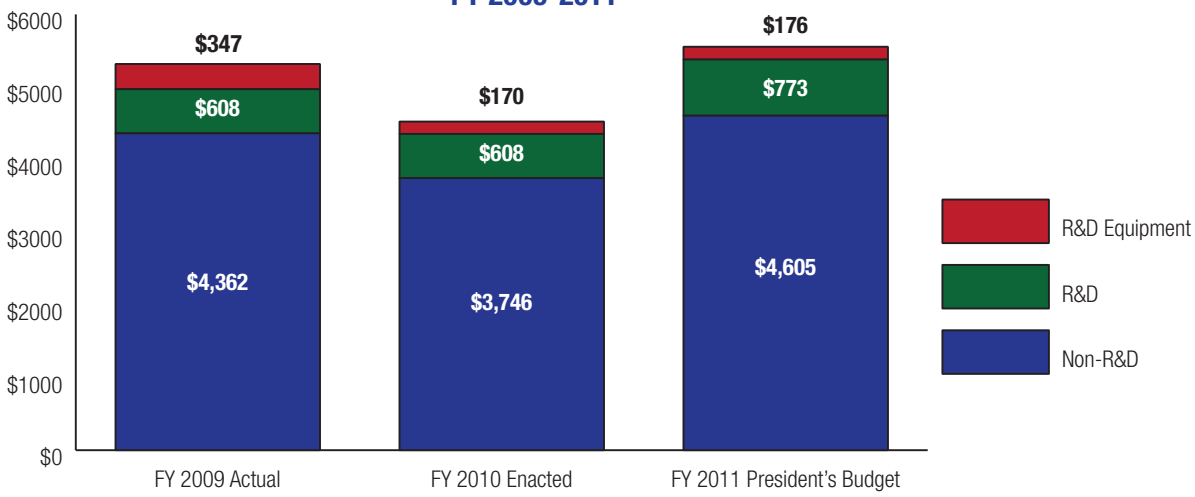
(3) providing probability and quality information that represents probabilities without the bias usually inherent in these types of forecasts.

HEFS also includes tools to allow not only generation of post-event verification measures but also measures of quality forecasters can use prior to issuing the forecasts. Hydrologic forecasts are a critical product produced by the NWS. Hydrologic models, using input from atmospheric models, are the cornerstone of the products disseminated by NWS River Forecast Centers and Weather Forecast Offices to emergency managers, the public, and state and federal agencies. Decisions by these entities affect many lives and dollars.

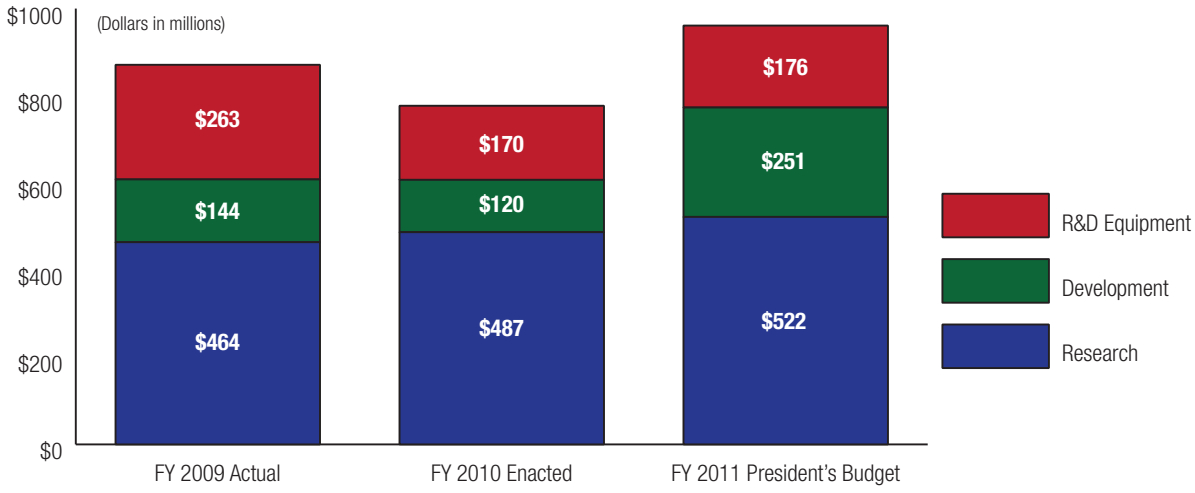
The following charts display the scope and nature of R&D at NOAA:

- R&D represents 13.9 percent of total NOAA funding for FY 2011. R&D equipment also accounts for 3.2 percent of NOAA's total FY 2011 request.
- NOAA has included some of the Joint Polar Satellite System sensors in R&D. This change accounts for the increase in NESDIS's share of NOAA's R&D and the increase in extramural R&D.
- 48 percent of NOAA's R&D is intramural and 52 percent is extramural.
- NOAA's R&D budget is 68 percent research and 32 percent development.
- NOAA's Office of Oceanic & Atmospheric Research (OAR) manages 46 percent of NOAA's R&D. The remainder is distributed among the operational Line Offices.
- Through NOAA's Office of Marine and Aviation Operations and through OAR's High Performance Computing capabilities, NOAA's FY 2011 request includes $176 million for Research and Development Equipment.

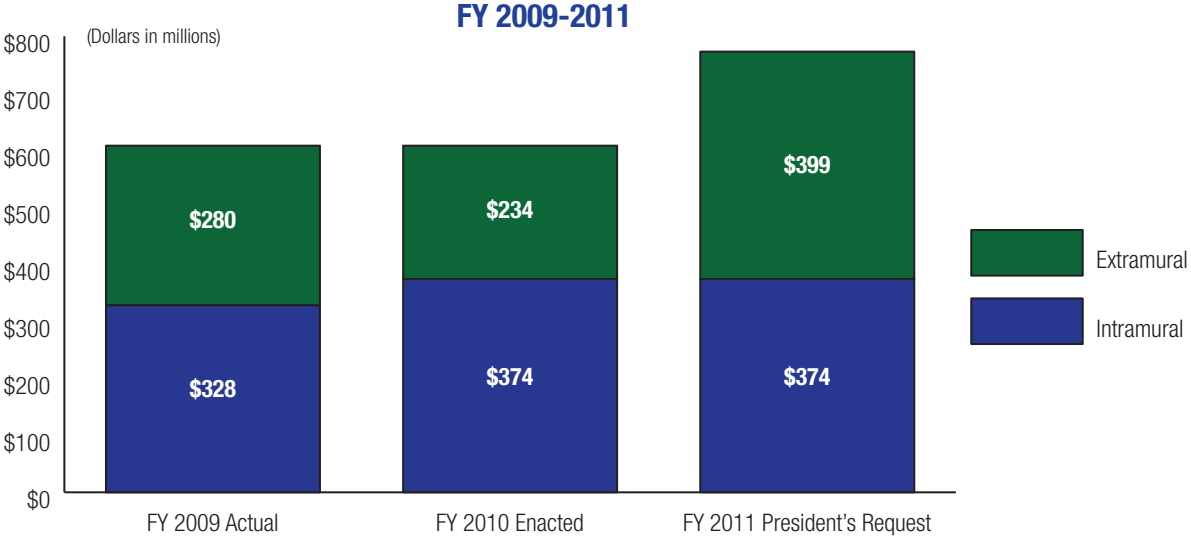
NOAA R & D FUNDING
FY 2009-2011



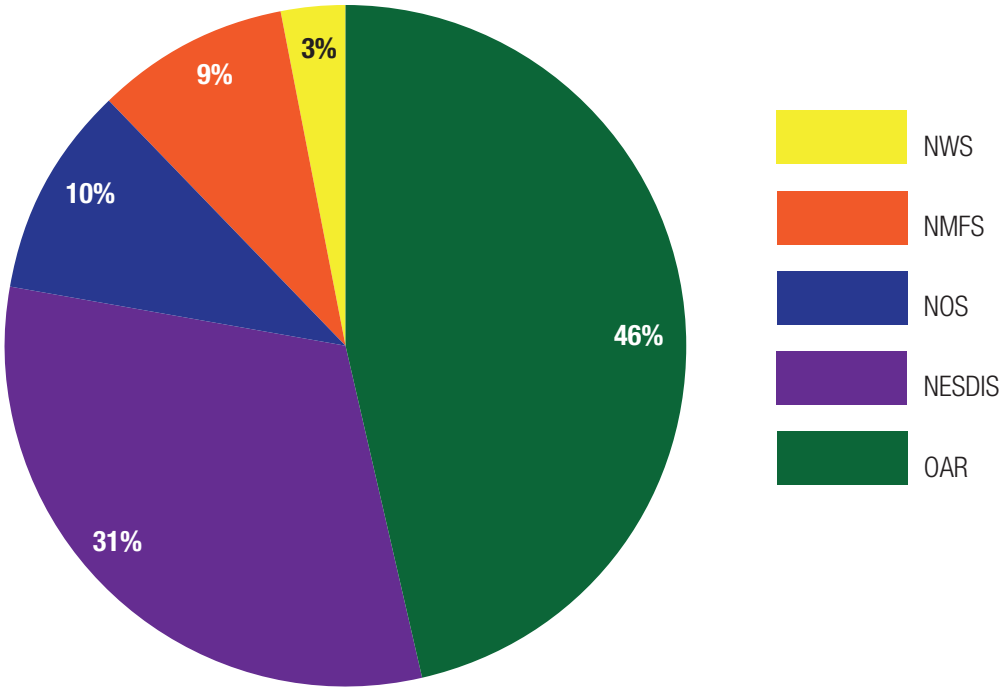
RESEARCH & DEVELOPMENT FUNDING
FY 2009-2011



EXTRAMURAL & INTRAMURAL FUNDING
FY 2009-2011



FY 2011 R & D BUDGET BY LINE OFFICE



FY 2011 R & D BUDGET BY GOAL